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THE IMPACT OF LOW BIRTH WEIGHT ON NORTH CAROLINA NEONATAL MORTALITY

by

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ABSTRACT

Birth-weight standardization was used to compare North Carolina neonatal mortality to that in the United States and also to examine trends. It was found that the higher neonatal mortality rate in North Carolina as compared to the United States can be attributed to lower birth weights, rather than higher weight-specific neonatal death rates. If North Carolina births had the same distribution by weight as those in the United States as a whole, the North Carolina neonatal mortality rate would be lower than the United States rate, rather than 15 percent higher as occurred in 1980. Further, almost all of the decline in neonatal mortality in North Carolina since 1976 has come about as a result of improved neonatal survival at the low birth weights, rather than from improvement in the birth-weight distribution. It was also found that the nonwhite neonatal mortality rate in North Carolina is higher than the white rate (67 percent higher in 1980) because of lower nonwhite birth weights, and if nonwhites had the same birth-weight distribution as whites the nonwhite neonatal mortality rate would be lower. It is suggested that further major declines in North Carolina neonatal mortality can be achieved only if measures are taken to substantially reduce the number of low-birth-weight babies. As well as preventing neonatal deaths, improving the birth-weight distribution would decrease neonatal morbidity and reduce neonatal intensive care costs.

INTRODUCTION

Infant mortality is an important problem in both the United States and North Carolina. In 1978 the United States ranked only 17th among industrialized Western nations in terms of low infant mortality (*1*), and the State of North Carolina has one of the highest infant mortality rates in the United States (*2*). Neonatal mortality (deaths from birth to 28 days of age) is a large component of infant mortality, accounting for 69 percent of 1980 North Carolina infant deaths (*3*). Of these neonatal deaths, 63 percent occurred under one day of age and 86 percent occurred under 5 days of age. Neonatal deaths are more amenable to prenatal prevention strategies than post-neonatal deaths (age 28 days to one year) which are more frequently associated with socio-economic and environmental conditions occurring after the perinatal period.

One of the most important factors contributing to neonatal death is low birth weight (*4,5,6*). In North Carolina in 1980, 71 percent of infants weighing less than 1000 grams died before 28 days of age compared to 0.2 percent of infants weighing over 2500 grams. Therefore, in comparing overall neonatal mortality rates between areas, it is important to control for differences in birth-weight distributions before drawing conclusions about the relative levels of mortality risk. This is very similar to standardizing or adjusting crude death rates for differences in age distribution. Guyer et al. (*1*) recently standardized Massachusetts' neonatal mortality to the birth-weight distribution of Sweden and found that the resulting rate was 3 percent lower than that of Sweden, compared to a crude (unstandardized) Massachusetts neonatal death rate 58 percent higher than that of Sweden. In this paper we will compare North Carolina neonatal mortality to that of the United States in a similar manner, and assess the contribution of changing birth weight to neonatal mortality trends in North Carolina since 1976.

METHOD

The main statistical method used in this study is birth-weight standardization by the direct method. In this calculation, birth-weight-specific neonatal mortality rates are weighted according to a hypothetical or "standard" distribution of births. For example, multiplying the North Carolina death rates for each birth-weight category times the number of births expected if North Carolina had the same percent distribution of births by weight as the United States would yield a certain number of expected neonatal deaths. Computing an overall neonatal mortality rate using this expected number of deaths allows assessment of how much birth-weight distribution contributes to the higher overall neonatal mortality observed in North Carolina.

Neonatal deaths by birth weight are derived annually in North Carolina by automated and manual matching of each infant death certificate to the infant's birth certificate, from which birth weight and other infant as well as maternal information is obtained. Reports are received for events occurring in surrounding states that involve North Carolina residents, so that virtually all North Carolina resident neonatal deaths are included.

Birth weight is more than just a measure of grams. "Since birth weight serves as an intermediate outcome for many variables associated with infant mortality, birth weight can be viewed as a summary measure of the effect of these social and demographic risk factors" (*7*). Low-weight infants include those born too early (low gestational age) as well as those born too small due to intrauterine growth retardation. Low-weight infants are highly susceptible to a variety of life-threatening conditions. Although a combined measure of gestational age and birth weight might be the most appropriate indicator of prematurity, there is considerable rationale for focusing on birth weight as a single outcome measure. Birth weight alone has been shown to explain the variance in perinatal mortality almost as well as a combined index of gestational age and birth weight. Furthermore, vital statistics data on gestational age have been less reliable than the birth weight data and nonresponse is high (*7*). While greater birth weight will not prevent problems such as congenital anomalies in some babies, and very heavy babies may have special problems of their own, in most cases birth weight is a very good measure of survival potential.

Wilcox and Russell (*8*) have suggested that standardizing neonatal mortality for birth weight is biased against the population with higher birth weights. For example, the standardized neonatal mortality rate of the population with lower birth weights will be understated if the standardization is based on the birth-weight distribution of the population with higher birth weights. Their argument assumes that the schedule of weight-specific mortality weights of a population is primarily a function of the mean birth weight, and that increasing the mean birth weight (as is hypothetically done in standardization) would necessarily involve a corresponding shift in the weight-specific mortality rates. Thus they suggest it is not reasonable to increase birth weights via standardization and at the same time hold mortality rates constant. To the extent that the weight-specific mortality rates of a population are determined by biology, medical care, and other factors that might not change with an increase in the mean birth weight, the magnitude of the bias that they propose would be reduced. In any case, adjusting the standardized rates in the present paper for this possible bias would not alter any of the major findings or conclusions.

RESULTS

Comparison to the United States

In 1980 there were 830 neonatal deaths in North Carolina out of 84,481 live births for a rate of 9.8 neonatal deaths per 1000 live births. United States data for 1980, the latest available, show a crude neonatal death rate of 8.5 (9), which is 13 percent lower than the North Carolina rate. If, however, we assume that North Carolina births had the same weight distribution as United States births, a different picture emerges (Table 1).

In North Carolina 7.9 percent of 1980 births were below 2501 grams, compared to 6.8 percent in the United States. If North Carolina had experienced the same birth-weight distribution as the United States, 932 fewer infants of low birth weight would have been born in North Carolina in 1980. Applying the United States percent distribution by weight to the 84,481 North Carolina births in 1980 and then applying the North Carolina weight-specific neonatal death rates to these births results in 692 expected neonatal deaths. Thus if the North Carolina birth-weight distribution in 1980 had been the same as that in the United States, 138 fewer neonatal deaths would have occurred, without any change in the weight-specific survival rates. Further, the North Carolina neonatal mortality rate would be 8.2 rather than 9.8, a 16.3 percent reduction and below the U.S. rate of 8.5 rather than higher as actually occurred.

We conclude that neonatal mortality is higher in North Carolina than in the United States because of a less favorable birth weight distribution and, in fact, weight-specific neonatal death rates are on the whole lower in North Carolina.

Neonatal Death Rates by Race

Standardizing the North Carolina neonatal mortality rate in the manner shown above does not take into account that the percent nonwhite in North Carolina is higher than that in the United States. On the average, nonwhites have a substantially higher percent of low-weight births than whites. If one assumes that it is not reasonable for nonwhites in North Carolina to achieve the same birth-weight distribution as the U.S. average in the near future, then the approach of doing race-specific standardization would be appropriate. In North Carolina the white and nonwhite neonatal mortality rates in 1980 were 8.1 and 13.5, compared to the United States rates of 7.5 and 12.5. If North Carolina whites and nonwhites had the same birth-weight distributions as their white and nonwhite counterparts in the United States, and there were no change in the North Carolina race-weight-specific neonatal death rates, the 1980 North Carolina white neonatal mortality rate would be 7.5 and the nonwhite rate would be 12.0. Thus, even when each race is considered separately, the higher North Carolina neonatal death rate can be attributed entirely to lower birth weights.

A very interesting finding that emerges from this race-specific analysis is that 1980 North Carolina nonwhite weight-specific neonatal death rates were **lower** for every weight category than the comparable white rates. This was also true in North Carolina for 1981, and other studies have consistently shown substantially lower nonwhite neonatal mortality rates for birth-weight categories under 2501 grams (*10,11,12*). David and Siegel (*12*)

Table 1

Standardization of North Carolina's Neonatal Mortality Rate (NMR) to the Birth-Weight Distribution of the United States in 1980*

Birth Weight in Grams	North Carolina Actual				United States	North Carolina Expected		
	No. Of Live Births	% Of Live Births	No. Of Neonatal Deaths	Neonatal Deaths Per 1000 Live Births	% Of Live Births	No.Of Live Births	No. Of Neonatal Deaths	Neonatal Deaths Per 1000 Live Births
≤1000	611	0.72	432	707.0	0.54	457	323	
1001-1500	637	0.75	94	147.6	0.61	515	76	
1501-2000	1259	1.49	55	43.7	1.32	1116	49	
2001-2500	4204	4.98	61	14.5	4.37	3691	54	
≥2501	77770	92.06	188	2.4	93.16	78702	190	
Total	84481		830	9.8		84481	692	8.2

*Crude N.C. NMR (actual) is 9.8 per 1000 live births; standardized NMR (expected) is 8.2 per 1000 live births. The 1980 United States crude NMR is 8.5 per 1000 live births.

Note: A few North Carolina births (26) and neonatal deaths (14) of unknown birth weight have been allocated to birth-weight categories according to the percent distribution of those with known birth weight.

suggest that this differential holds up even after controlling for differences in gestational age. Thus the higher overall nonwhite neonatal mortality rate in North Carolina in 1980 (13.5 versus 8.1 for whites) was clearly due to lower nonwhite birth weights. Compared to a white percent of 6.1, the percent of nonwhite births under 2501 grams was nearly twice as high at 11.9 in 1980. For births under 1501 grams, where neonatal mortality is especially high, the nonwhite percent was almost two and one half times the white percent. If nonwhite births in North Carolina had the same weight distribution as white births, nonwhite neonatal mortality would be 6.7 compared to 8.1 for whites, assuming no change in the weight-specific death rates. It should be mentioned, however, that nonwhite postneonatal death rates are substantially higher than the white rates for every birthweight category.

Recent Trends

1976-1980

The contribution of changing birth weights to the decline of North Carolina neonatal mortality from 12.9 in 1976 to 9.8 in 1980 was also examined. It was found that practically none of this reduction can be attributed to increased birth weights. The percent of births under 2501 grams was 8.3 in 1976 and 7.9 in 1980. But the percent of births under 1000 grams actually increased from 0.61 in 1976 to 0.72 in 1980, with most of this increase occurring among nonwhites. Part of this increase could, however, be due to better reporting in 1980 of very low-weight deliveries as live births rather than as fetal deaths (*12*). But if we apply the 1976 North Carolina birth-weight distribution to 1980 births and assume the same 1980 weight-specific neonatal death rates, the expected rate of 9.2 is actually lower than the observed rate of 9.8. Therefore, the decline in neonatal mortality from 1976 to 1980 is due to reductions in weight-specific neonatal death rates. The rates in the under 1001 grams, 1001-1500, 1501-2000, 2001-2500, and greater than 2500 grams birth-weight categories declined by 17, 49, 47, 36 and 24 percent, respectively, over this period. These decreases in the low-weight death rates are associated with steady increases in the percent of low-weight births occurring in Level III (tertiary care) hospitals, where weight-specific death rates decreased from 1976 to 1980. Among births under 2501 grams, the percent occurring in Level III hospitals was 35.8 in 1976 compared to 44.0 in 1980. For the 1001-1500 grams category, the percents were 43.0 and 63.1.

1981-1982

The analysis of neonatal mortality into two major components sheds considerable light on the 1982 upturn in infant mortality in North Carolina. Much has been said about the increase in the infant mortality rate from 13.2 in 1981 to 13.7 in 1982, an increase that could be expected to result from random changes nearly 4 times out of 10. Further investigation, however, reveals that **all** of this increase in the infant mortality rate was due to an increase in neonatal mortality, and in fact all of this increase in neonatal mortality was among nonwhites. Neonatal deaths increased from 739 in 1981 to 813 in 1982, or from 8.8 neonatal deaths per 1000 live births to a rate of 9.5 in 1982. The postneonatal death rate declined slightly from 4.4 in 1981 to 4.3 in 1982. Looking at this by race, the white neonatal mortality rate was 6.9 in both 1981 and 1982, while the nonwhite rate increased from 12.3 to 14.7.[1] We would expect this 20 percent increase in the nonwhite neonatal death rate to occur due to random changes less than 2 times out of 100. Postneonatal deaths per 1000 live births declined by 8 percent for nonwhites, while increasing 3 percent for whites.

The increase in neonatal mortality from 1981 to 1982 was associated with a worsening of the birth-weight distribution. The percent of births less than 2501 grams increased slightly from 7.9 to 8.0, but the number of births under 1000 grams increased by 47 from 586 to 633, or from 0.70 percent of all births to 0.74 percent. This general pattern of change is also apparent for the two racial groups. Yet the increase in the prematurity rate among nonwhites accounts for only a small proportion of the overall increase in the nonwhite neonatal mortality rate. If 1981 nonwhite births are assumed to be distributed by weight like those in 1982 (in percentage terms) and then the actual 1981 weight-specific death rates are applied, an expected nonwhite neonatal mortality rate of 12.5 results. Thus lower birth weights explain only around 8 percent of the 1981-1982 increase in the nonwhite mortality rate from 12.3 to 14.7.

An examination of changes in the weight-specific neonatal death rates from 1981 to 1982 sheds more light on this problem. Table 2 displays these changes. For total births, three of the rates increased and two decreased, though none of these changes was statistically significant at the $p = .05$ level. For whites also none of the changes was significant. For nonwhites, 4 of the 5 rates increased from 1981 to 1982 and two of these increases were significant at below the .05 level.[2] These data confirm that the increase in the overall nonwhite neonatal mortality rate was due substantially to increases in weight-specific death rates, as well as to an increase in low-weight births. These increases in the weight-specific death rates were not associated with a decreasing percent of births in these weight categories occurring in Level III hospitals.

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[1]It should be noted that the race-specific death rates using race at birth from the matched birth/infant death file, which are shown here, may differ slightly from the rates using race as assigned on the death certificate.

[2]See, however, the first note to Table 2.

Table 2

Changes in Birth-Weight-Specific Neonatal Deaths per 1000 Live Births by Race, North Carolina 1981—1982

Birth Weight in Grams	Total				White				Nonwhite			
	1981 Rate	1982 Rate	% Change	p	1981 Rate	1982 Rate	% Change	p	1981 Rate	1982 Rate	% Change	p
≤1000	691.1	687.2	-0.6	.94	723.9	675.4	-6.7	.52	651.3	695.8	6.8	.47
1001-1500	110.1	132.8	20.6	.24	163.5	164.1	0.4	.98	53.5*	101.2	89.2	.03
1501-2000	44.8	33.2	-25.9	.13	55.1	43.1	-21.8	.32	30.2	23.0	-23.8	.45
2001-2500	11.5	14.1	22.6	.29	12.0	13.8	15.0	.60	10.5	14.4	37.1	.28
≥2501	1.9	2.1	10.5	.37	1.9	1.8	-5.3	.70	1.8	2.8	55.6	.02
Total	8.8	9.5	8.0	.13	6.9	6.9	0.0	1.00	12.3	14.7	19.5	.02

*This rate is extremely low and probably does not represent the underlying or "true" rate in 1981. The comparable rate in 1980 was 110.7.

Note: The probability (p) values indicate the probability that a change as large as the one observed could have occurred due to random fluctuations in the rates, considering the number of deaths in the numerators. For example, .02 would indicate 2 times out of 100.

Considering also that there were increases in certain race-weight-specific death rates from 1980 to 1981, it appears that the consistent decline of weight-specific neonatal mortality rates that has occurred since at least 1976 has temporarily abated.

DISCUSSION

This study shows clearly why examination of "crude" neonatal or infant mortality rates is not sufficient. It is essential that birth-weight-specific mortality rates be examined in relation to the distribution of births by weight. In order to undertake such analysis, matched birth and infant death files are required. Given that the relatively poor ranking of the United States among industrialized nations with regard to neonatal mortality is due largely to low birth weight (*4*), it is difficult to justify why such data are not available for the entire United States for the direction of national policy.

The results of this analysis have some important implications for North Carolina policies designed to further reduce the neonatal mortality rate. Almost none of the reduction in neonatal mortality since 1976 has been due to increased birth weights. The major improvements in neonatal mortality have resulted from better medical care of small babies in neonatal intensive care units (*1,10,13*), which has served to reduce the weight-specific neonatal death rates particularly in the 1001 to 2500 grams categories. Williams and Chen (*13*) suggested that the increased rate of cesarean section for low-weight infants also contributed to the decline of neonatal death rates in California. They found that decreases in birth-weight-specific mortality accounted for 85 percent of the decline of the neonatal mortality rate in the 1970s, with only 15 percent due to improvements in birth weight, and no improvement was observed in the birth-weight distribution for blacks. Goldenberg et al. (*10*) found that only 5 percent of the nearly 50 percent reduction in neonatal mortality in Alabama from 1970 to 1980 could be attributed to changes in birth-weight distributions, and birth-weight changes accounted for 12 percent of the decrease in the white neonatal mortality rate but none of the decrease in the nonwhite rate. David and Siegel (*12*) found for North Carolina that "better babies," as reflected primarily in increased birth weights but also considering gestational age, accounted for 85 percent of the decline in neonatal mortality from 1968 to 1972, but accounted for only 16 percent of the decline from 1972 to 1977 with the rest of the decline attributable to better weight-specific survival rates or "better care." They also found that improved birth weights and gestational ages were a much less important factor in the decline of neonatal mortality for nonwhites, as compared to whites.

It may be that in the near future further major reductions in neonatal mortality will require more than efforts to increase weight-specific neonatal survival after birth, though some improvement may occur by extending neonatal intensive care services to persons that have not had access to them. The birth-weight standardization carried out above suggests that North Carolina weight-specific neonatal death rates are probably already below the United States rates. Goldenberg et al. (*14*) have presented the lowest average weight-specific neonatal mortality rates reported in the medical literature for the 1976-1980 period, and the average 1976-1980 rates for North Carolina were 20 to 65 percent higher than these lowest "literature" rates. By 1981, however, the North Carolina annual rates were below these lowest average 1976-1980 rates for all weight categories except 2001-2500 grams where they were equal. The trend in weight-

specific rates from 1981 to 1982 (Table 2) indicates that future large increases in neonatal survival rates will be difficult to attain. If we apply the 1979 Swedish birth-weight distribution to 1979 North Carolina births and assume that 1979 North Carolina weight-specific neonatal death rates would be in operation, the expected rate is 5.6 compared to 5.0 in Sweden in 1979 and compared to an actual North Carolina 1979 rate of 10.4. Thus North Carolina weight-specific neonatal death rates appear to be very close to those in Sweden, which has one of the lowest crude neonatal death rates in the world.

This suggests that, with existing technology, further large reductions in neonatal mortality in North Carolina are not likely to result from neonatal intensive care and other methods that increase the rate of survival after birth, through certainly some improvements can be made in this area by extending these services to groups that have not had access to them in the past. If North Carolina is to reduce neonatal mortality to the United States average or lower, we must adopt policies that will lead to a substantial reduction in low-weight births.

The results above show that the North Carolina racial gap in neonatal mortality could be eliminated and in fact reversed if North Carolina nonwhites achieved the birth-weight distribution of whites, with no change in neonatal survival rates. Several of the studies cited above indicated that improved birth weights have been a much less important factor in the decline of nonwhite neonatal mortality, compared to whites, including the study by David and Siegel (*12*) for North Carolina during the 1968 to 1977 period. Goldenberg et al. (*10*) found for Alabama that shifts in birth-weight distributions for nonwhites from 1970 to 1980 would have **increased** the neonatal mortality rate if weight-specific death rates had not been declining at the same time.

The data in the present study show a widening racial gap in neonatal mortality: the nonwhite crude neonatal mortality rate was 35 percent higher than the white rate in 1976, 67 percent higher in 1980, 77 percent higher in 1981, and 113 percent higher in 1982. The percent of nonwhite births weighing less than 2501 grams remained almost exactly twice the white percent over this 1976-1982 period (12.1 versus 6.1 in 1982), but the percent of births under 1001 grams for nonwhites changed from 2.3 to 2.9 times the white percent. Death rates in this very low weight category have not declined as rapidly as those in the 1001-2500 grams categories. The ratio of nonwhite to white neonatal death rates at each weight category did not change substantially from 1976 to 1980. From 1981 to 1982, the weight-specific death rates for nonwhites worsened considerably in comparison to the white rates, contributing to the widening racial gap (Table 2). In fact, the nonwhite neonatal death rate was higher than the white rate in 1982 for three of the birth-weight categories, where in 1980 and 1981 all of the weight-specific nonwhite rates had been lower. The worsening of these nonwhite rates from 1981 to 1982 in comparison to the white rates was not associated with a relatively lower percent of nonwhite births in these weight categories occurring in Level III hospitals.

These recent increases in nonwhite weight-specific neonatal death rates are cause for concern, particularly the increase in the over-2500-grams category (Table 2). But there is still a critical need to reduce the high rate of low-weight births among nonwhites in North Carolina, and much room for improvement. "The intensive care approach alone will not suffice to close the racial gap in newborn mortality" (*12*). Williams and Chen (*13*) suggest that the most obvious target for continuing the decrease in perinatal mortality rates is the reduction of low-weight births among blacks, and the data in the present study support this conclusion. Prenatal medical care strategies alone are not likely to solve this problem, since the weight distribution of live births in any population is closely linked to aspects of social class (*4*). Low birth weight is strongly associated with low socio-economic status (*5*).

The application of neonatal intensive care technology has led to very rapid increases in neonatal survival rates, but strategies to increase birth weights may not show such rapid results. Immediate interventions such as more prenatal care visits, nutritional supplementation, or the use of labor-inhibiting drugs (*15*) will help, but the reduction of low birth weight is also a long-term process tied to overall socio-economic development and associated factors such as better education, employment opportunities, and incomes. Though these changes may be difficult to implement, they are nevertheless very important. Further improvements in neonatal mortality through postnatal medical interventions are not only limited, they are also very costly. Prevention of low-weight births will reduce not only the overall neonatal mortality rate but also neonatal intensive care costs. Sweden, which has about the same number of deliveries per year as North Carolina, has only about half as many low-weight births and neonatal deaths, and about half the number of ventilator-equipped neonatal intensive care beds as in North Carolina (*12*).

While the outcome measure in this study was neonatal mortality, another result of increasing birth weights would be the reduction of neonatal morbidity. Low-weight babies are at higher risk for intracranial hemorrhage and birth asphyxia (*12*). Without losing sight of the positive contribution of intensive perinatal medical care in reducing morbidity (*16*), "a strategy aimed at reducing the prematurity rate should be more effective in reducing morbidity in the population than a strategy focused primarily on helping premature babies survive, once factors have combined to cause a premature birth" (*12*).

In summary, this study has shown that North Carolina's higher neonatal mortality is due entirely to lower birth weights, when compared to the United States, and that little improvement in birth-weight distribution has occurred since at least 1976. Further, from 1981 to 1982 the percent of low-weight births actually increased. Clearly, a major part of our agenda for preventing future neonatal deaths in North Carolina should be the implementation of programs that reduce the number of low-birth-weight babies.

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